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PROPOSALS ON MINE WATER CONTROL SYSTEM FOR KOTREDEZ COAL MINE

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ABSTRACT

Kotredez Mine located in the Zasavski Miocenic Brown Coal Basin in Yugoslavia was partially flooded by a karstic water inrush carrying a large amount of solid particles. Hungarian Institutions, organizations led by our Institute were contributing to the operations, measurements and to help by planning and design of the urgent and long term control measures. The paper discusses the estimation of the key hydrogeological data, the planning of the variables of the control systems, the design of the drainage and sediment treatment plants.

1. PRELIMINARIES

The Kotredez Colliery is located in the Zasavski Brown Coal Basin of miocenic age in Slovenia, Republic of Yugoslavia. The geological-hydrogeological situation is shown schematically in the cross section of Fig. 1/a. The inclined coal seam was exploited by applying horizontal slices and using normal and/or sublevel cavings. The schematic map of the actual mine operations is presented in Fig. 1/b. During the 5o years history of this mine serious water accidents never occured, only small water/thermal water inflows from the dolomite bedrock were mentioned. In 1928 two big water inrushes occured which had 2.9 m³/min constant recharge after blocking with concrete dam. Small water inrushes with low solid particle content occured six times in 1955 and 1974. These were blocked within short time. In March 1981 5-6 m³/min karstic water inrush with high solid particle content appeared in the main roadway of the 8th level. Because of the high volume of sediments the pumping station of the 8th level could not operate and the 8th level developed newly was totally flooded. At this time the representative of our Institute /A.Schmieder/ was invited to participate in a consultation. During these discussions several decisions were

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taken with regard to the necessary control measure /the main way of control, horizontal and vertical holes for drainage, blocking of water inrush at 8th level, etc./ After some months the solid content of water inflow sealed the water channel or the roadway itself. Though no reopening operations were carried on at that time, in October 1981 the water inrush was renewed with a duplicated yield /12 m³/min/. The great volume of the solid sediment heavily damaged even the main pumping station at level 6. The actual location of the renewed inrush was also unknown because levels 7 and 8 were totally flooded with water and sediments and the water and sediment entered into the main haulage roadway of level 6 at many inclined cuts. /See Fig. 1/b/

Urgent assistance of the Central Institute of Mining Development of Hungary was requested by the mine management /on the basis of a friendly cooperation during the last 15 years/. /Schmieder-Martos 1968, Zoltán-Bogdány 1971, Kesserü 1976, Schmieder-Honvéd 1979, Schmieder-Havasy-Kesserü 1977/. New pumps from the Hungarian Central Mine Emergency Store were provided and regulated by the staff of Dorog Coal Company /Hungary/. Large diameter pilot holes for searching the location of the inrush were bored by the staff of the Hungarian Shaft Sinking Company /this staff was led by I.Benke Min.E./ Acoustic and conventional geophysical logging in holes, geoelectrical and microseizmic loggings at level 6 were successfully used for detecting the location of the inrush and for determining the thickness of roof clay layers. /The underground geophysical measurements were carried on and interpreted cooperatively by the staffs of the Geophysical Department of Mining Faculty Miskolc, Hungary/ and by the Geophysical Section of the Central Institute of Mining Development /Budapest, Hungary/ /Hursán L. 1982. Fábiáncsics L. 1982/. The manager and principal consultant of the Hungarian assistance has been dr. A.Schmieder the chief geothechnical engineer of the Central Institute for Mining Development.

As a result of the above listed efforts the location of the inrush was determined, but a large damaged area of the roof protective barrier was also detected. Under those conditions a quick and effective sealing of the inrush seemed to be impossible /Schmieder 1982/, consequently other ways of process control were considered/designed by the staff of Rudarsko Elektroenergetski Kombinat, Trbovlje /Mr. M. Malovrh Min.E. R.Ozbic Min.E. Mr. L.Grahek Min.E., Mr. M. Hocevar Min.E., Mr. R.Sikovec Min.E., Mr. G.Mitrevski Min.E. and others/.

The designer team of the Central Institute for Mining Development provided assistance also in this work in a close and friendly cooperation with the Geological Dept. of University of Ljubljana led by Prof.Kruscer and with the staff of Geoloski Zavod Ljubljana. All the above mentioned operations were governed by Rudarsko Elektroenergetski Kombinat Trbovlje and supervised by a governmental commission led by Prof.R.Ahcan. As a result of this friendly cooperation the drainage operations are carried on successfully. During the last three years the water table of a region of 3 km² dropped 335 m. The actual yield of drainage is 1o m³/min. Additional 11o m water level drop is predicted/planned.

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FIG 1/a

SCHEMATIC GEOLOGICAL CROSS SECTION

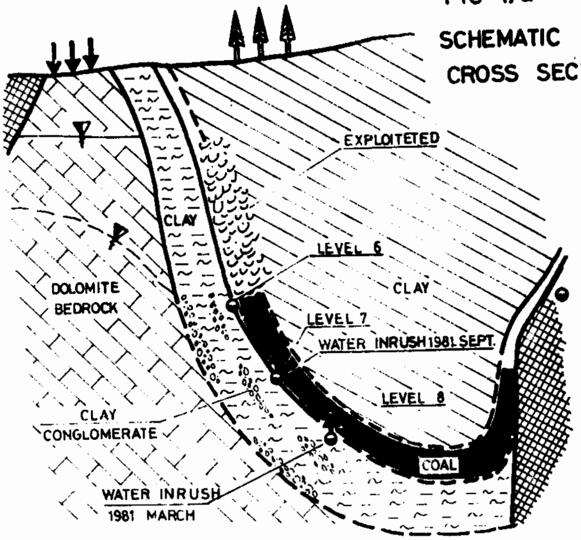

FIG. 1/b SCHEMATIC MINE MAP

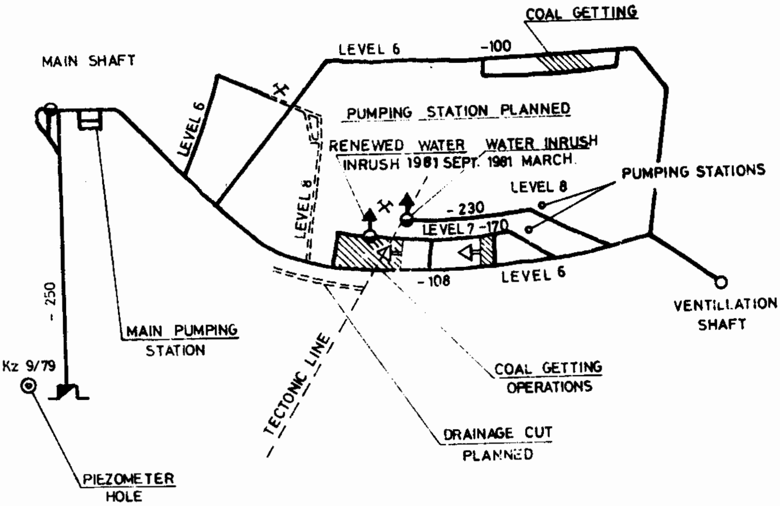

FIG. 1

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This paper presents hydrogeological estimations for determining the basic data for design, proposals on selection the proper way and system of control, some designs on drainage system and on water treatment.

2. HYDROGEOLOGICAL STUDIES

Though the complicated geological structure of the region was thoroughly studied /Kruscer I.1982/ and mining experiences, observations were also available on this mine and on other mines of the coal basin /Bozovic-Junez 1982/, the connection of the dolomite bedrocks with the large dinaric karstic massif and the ways and quantity of recharge were unknown. The drainage experiences of some mines in the vicinity /e.g.Ojstro Kisovec/ show quasi-separated dolomite reservoirs of medium water conductivity, because their recharge varied between 3-6 m³/min and no hydraulic interactions were detected between the drainage of the different mines.
Additional surface and underground hydrogeological investigations were carried on by Geoloski Zavod Ljubljana /Bozovic M. Junez P. 1982/. For determining the ways and quantity of recharge the data of piezometer holes /see Fig 2/a/ were analysed separately by the Geological Dept. of the University of Ljubljana and by the authors of this paper as well and the results of the two evaluations were compared. Our problem approach and results are summarized as follows:
- On the basis of the piezometer data the $S - \frac{ds}{dt}$ curve was determined /see Fig. 2/b/
- The feature of this empirical $S - \frac{ds}{dt}$ curve was compared with the characteristic curves of different recharge ways given by the solution of the differential water balance equations of reservoirs with different ways of recharge /see Fig. 3/a/.
- As a result of this comparison it seemed that the recharge had a constant praecipitation from rainfall /2 m³/min/ and an additional /lateral/ recharge of quasi linear dependency with the depth of water level lowering. /See Fig. 2/a/
For depressurizing the 8th level the recharge was estimated as 9-11 m³/min /see Fig. 3/b/.
The same results were determined by prof.Kruscer and our forecast also fits to the first preliminary prediction of A.Schmieder provided in July 1981.

On the basis of transmissibility evaluations from piezometer data in the vicinity of the water inrush and on empirical data of the surrounding mines evaluations were made also on the maximum short time yield of an individual inrush at level 8 /q_{max} 12 m³/min/.

3. DESIGN OF CONTROL MEASURES

Urgent measures were necessary first to protect the pumping at the 6th level against the long period effect of solid sediments, and to protect the main roadway against the effect of flowing water and from rock movements caused by the extraction of 60000 m³ of sediments from the area of the inrush.

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Simultaneously with urgent measures planning and design of the long term measures were also carried on.

The task of the Central Institute for Mining Development was as follows:

- to provide occasional consultancy on urgent measures,
- to provide variants of the system of long term control measures /for decision making/,
- to provide some specified detailed designs /e.g. the water treatment /for urgent and for the long term system as well.

3.1. The main way of mine water control

Because of the limited connection of the dolomite bedrock reservoir with the large karstic massifs and of the limited and known quantity of recharge /according to Chapter 2/ all partners did agree on the possibility and high necessity of the effective drainage of the dolomite reservoir bedrock. /This solution was originally planned and decided by the mining company on the occasion of the first inrush./

All proposals, decisions on urgent measures and all variaties of the system design were based on the above statement.

3.2. Proposals and decisions on urgent measures

Having determined the thickness of protective clay barrier between the haulage roadway of level 6 and the dolomite bedrock, and the location of the inrush and the main tectonic zones /see Fig. 1/b/, first a system of drainage wells were agreed upon, which system consists of quasi-horizontal wells along the main haulage way and of quasi-vertical wells located at the area of water inrush to decrease the yield and the solid particle ratio of the spontaneous inrush endangering the operation of the pumping station and the stability of the main haulage roadway. The drained water was planned to be conducted directly into the clear water sump of the pumping station by pipelines. The location of the drainage holes was planned and they were bored by Geoloski Zavod Ljubljana /Bozovic M. 1983/. All other operations were planned and realized by the staff of the mining company.
As standby measures the enlarging of the sump and settling capacity of the 6th level were also taken into considerations.

Variaties of the technological design for the extension of the settling capacity were prepared by the staff of the Central Institute for Mining Development of Hungary. Though the extension of settling was not realized because of the success of drainage mentioned before, one of the variaties is presented, herein, illustrating a special way of extending the sump capacity operating continuously under difficult conditions.

Due to many reasons /e.g. the difficulties of transportation at the haulage roadway covered by flowing water, the rock properties, etc./ new openings for settling had to be located in the near vicinity of the existing pumping plant. The maximum size /diameter/ of the new openings for settling was limited / 3,5 m/ because of the bad rock conditions.

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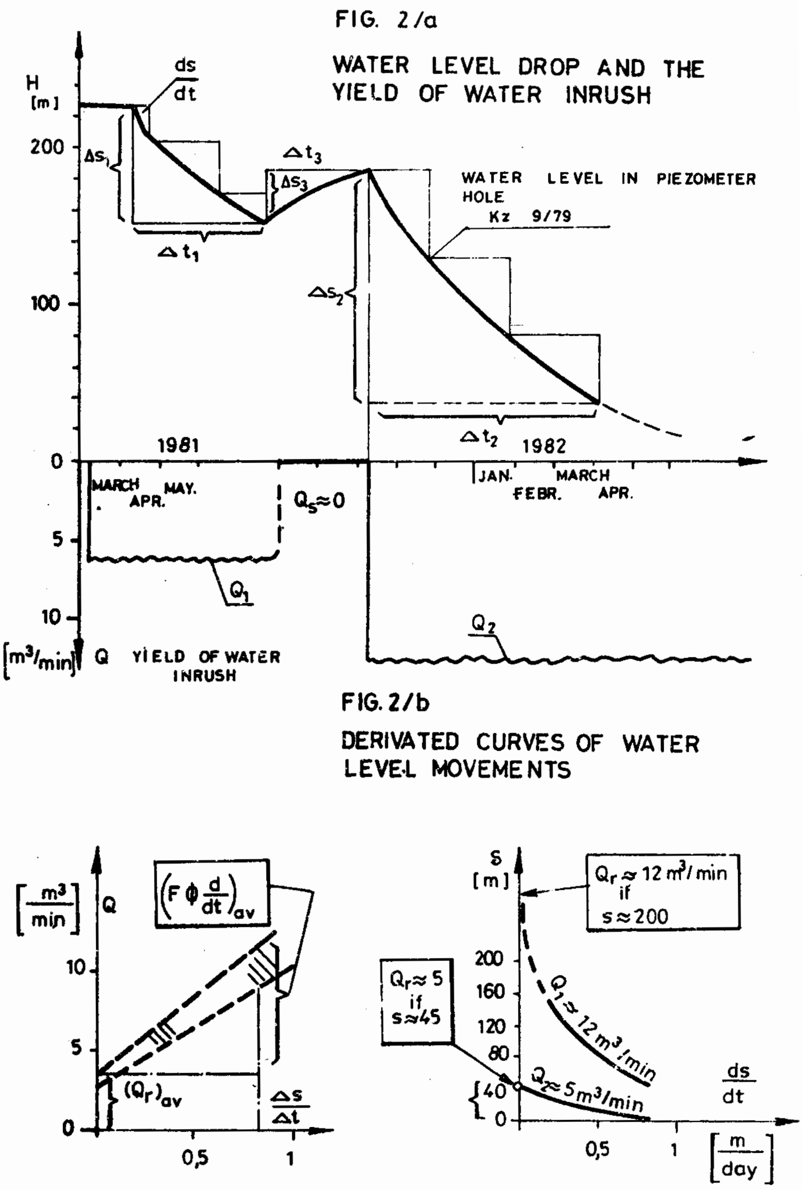

FIG. 2.

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FIG. 3/a DIFFERENT WAYS OF RECHARGE AND THE TYPES OF DERIVATED CURVES

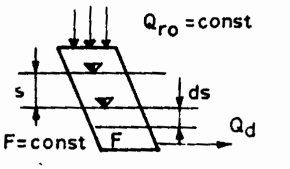
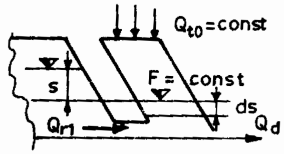
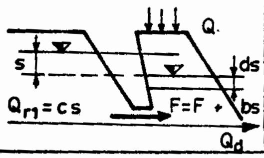
SCHEME OF RECHARGE	WATER BALANCE EQUATION	DERIVATED CURVES
	$Q_d = Q_{or} + \phi F \frac{ds}{dt}$	if $Q_d \cong const$ $\frac{ds}{dt} = const$
	$Q_d = Q_0 + \phi F \frac{ds}{dt} + c \cdot s$	if $Q_d \cong const$ $\frac{ds}{dt} = A - Bs$
	$Q = Q + \phi (F+bs)\frac{ds}{dt} +$ $+ cs$	if Q_d = const $\frac{ds}{dt} = \frac{A}{s} - B$

FIG. 3/b RECHARGE IN FUNCTION OF WATER LEVEL DROP AT PIEZOMETER HOLE Kz-9/79

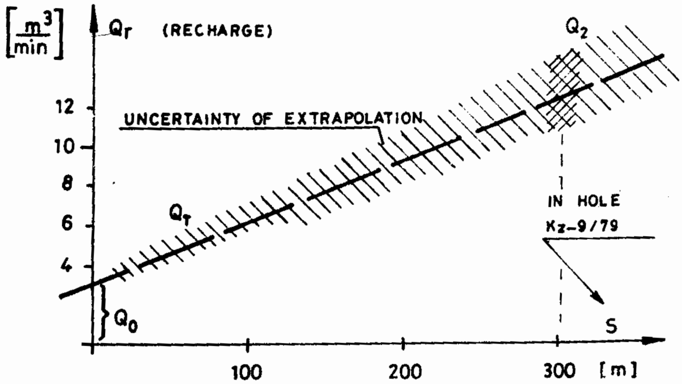


FIG. 3.

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The location map of one of the settlers is presented schematically in Fig. 4. /Bagdy-Perjés 1982/

After putting the new settlers into operations the modification of the old sumps were also planned by forming settler and clear water sumps with inserted water inlets and overflow dams /see Fig.4./. The capacity of the settler units and all details of the water distribution/inflow/outflow were carefully designed according to full scale settling and sediment removal tests carried on in the testing plant of our Institute /Bagdy-Kesserü 1978, Bagdy 1982, Bagdy-Kocsányi 1982/.

3.3. System versions for long term control

Considerations were first taken on versions of the drainage for protecting the planned operations at level 8. Because of the distroyed structure of the protective clay barrier in the area of the inrush, the protective effects of clay against the water pressure could not be taken into account. Total water level lowering up to the 8th level was planned.

The version of water level lowering by large diameter holes bored from level 6 equipped with submergible pumps was excluded mainly because of the difficulties of boring large diameter holes from the mine, although this version would provide the quickest solution.

Only the versions of gravitational way of drainage were taken into consideration by applying holes, drainage cut and by combining them.

According to hydrogeological estimations the water yield to be drained was evaluated for different versions as indicated below:

For drainage by holes

$$\left(Q_d\right)_1 = Q_r + Q_{st} + q_{ba}$$

where Q_r is the recharge, Q_{st} is the yield for draining the stored water in the fissures of the reservoir, q_{ba} is the maximum possible yield of a hole in case of insufficient operation of its preventer.

For drainage by cuts

$$\left(Q_d\right)_2 = Q_r + Q_{st} + q_{imax}$$

where q_{imax} is the maximum yield of a spontaneous inrush during driving the drainage cut.

For combined way of drainage

$$\left(Q_d\right)_1 < \left(Q_d\right)_3 < \left(Q_d\right)_2$$

Some other conditions and factors taken into considerations were as follows:

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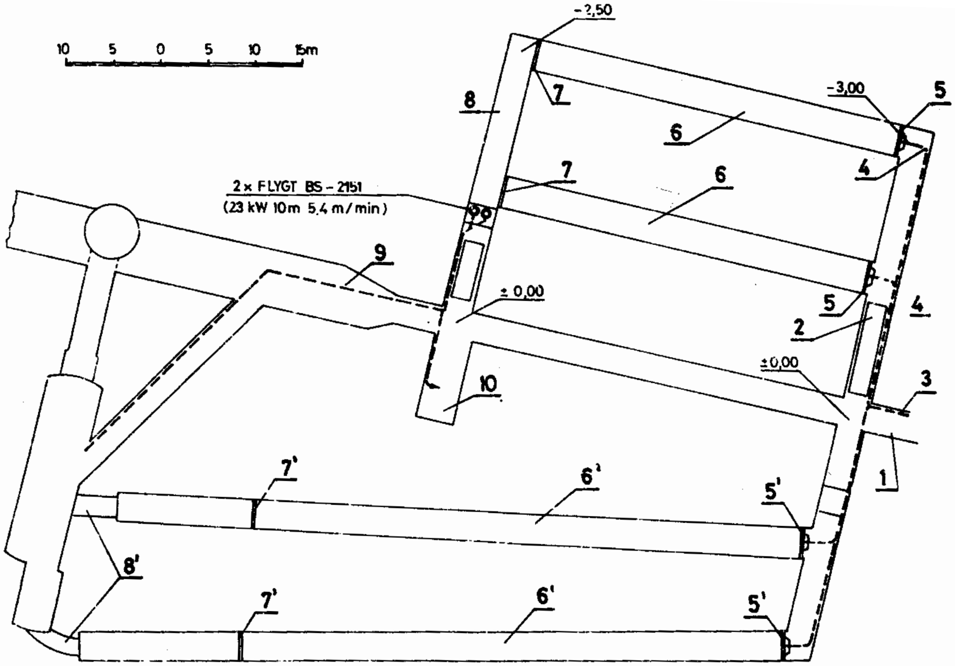

1 EXISTING SHAFT PLATFORM

2 UPPER WATER INFLOW AND CLEANING GALLERY

3 CONNECTIONS OF WATER INLET TO THE MIXER-DISTRIBUTOR

4 INFLOW PIPES φ 250 mm

5 AND 5' INFLOW WEIRS

6 AND 6' SETTLERS

7 AND 7' WATER OUTPUT OVERFLOW DAMS

8 AND 8' WATER OUTFLOW GALLERY

9 CLEAN WATER PIPE

FIG. 4 EXTENSION OF SETTLING CAPACITY AT THE MAIN PUMPING STATION LEVEL 6

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- Because of the damaged protective clay layer at level 8 an effective drainage barrier is extremely necessary in this area. A drainage cut can operate effectively, but with a gravitational drainage of boreholes a deeper location of holes is necessary to reach an effective protection.

- For the version of drainage cut the maximum capacity of settling is necessary because of the loosen tectonic zones in the dolomite bedrock.

- The drainage cut can also be utilised later as ventillation, or haulage roadway of operations at level 8.

The mine management decided to select the combined way of drainage. /See Fig. 5./

A "low pressure" water door was also planned by the mine management to eliminate the risk of flooding during energy pauses. For storing a water load of several meters even this water door will be suitable taking into account the damaged protective clay barrier.

More system variaties of pumping were also prepared by our Institute including high pressure submergible pumps or abrasion resistent low pressure pumps. Finally a conventional pumping plant equipped with Yugoslavian pumps was selected as shown in Fig. 5. The selected versions on pumping and drainage require a sediment treatment plant between the drainage cut and the pumping station. It was designed by our Institute. /Bagdy-Kesserü 1982/

3.4. Sediment treatment plant at level 8

The maximum short time yield of the combined way of drainage was estimated as 2o-22 m³/min. A part of this yield will be drained by holes, which will surely produce clear water, consequently the "dirty" water yield being treated is estimated as Q_d = 16 m³/min. For longer period the dirty water input of sediment treatment plant forecasted as $(Q_d)_1$ = 4-8 m³/min.

The volume of solids coming from one inrush was estimated as 2o-4oo tonns /from loosen tectonic zones crossed by the drainage cut/.

The requirements for the planned settling plant were as follows:

- Excellent settling effect and mechanized removal of the settled sediment for a long period "dirty" water input of 6-8 m³/min.

- "Acceptable" settling effect and removal for the short time dirty water input of 16 m³/min and 4oo tonns of solids.

To meet these requirements the sediment treatment plant consists of

- two /or alternatively/ three parallel settlers /short time capacity: 8 m³/min; long time capacity: 6,4 m³/min of dirty water/,

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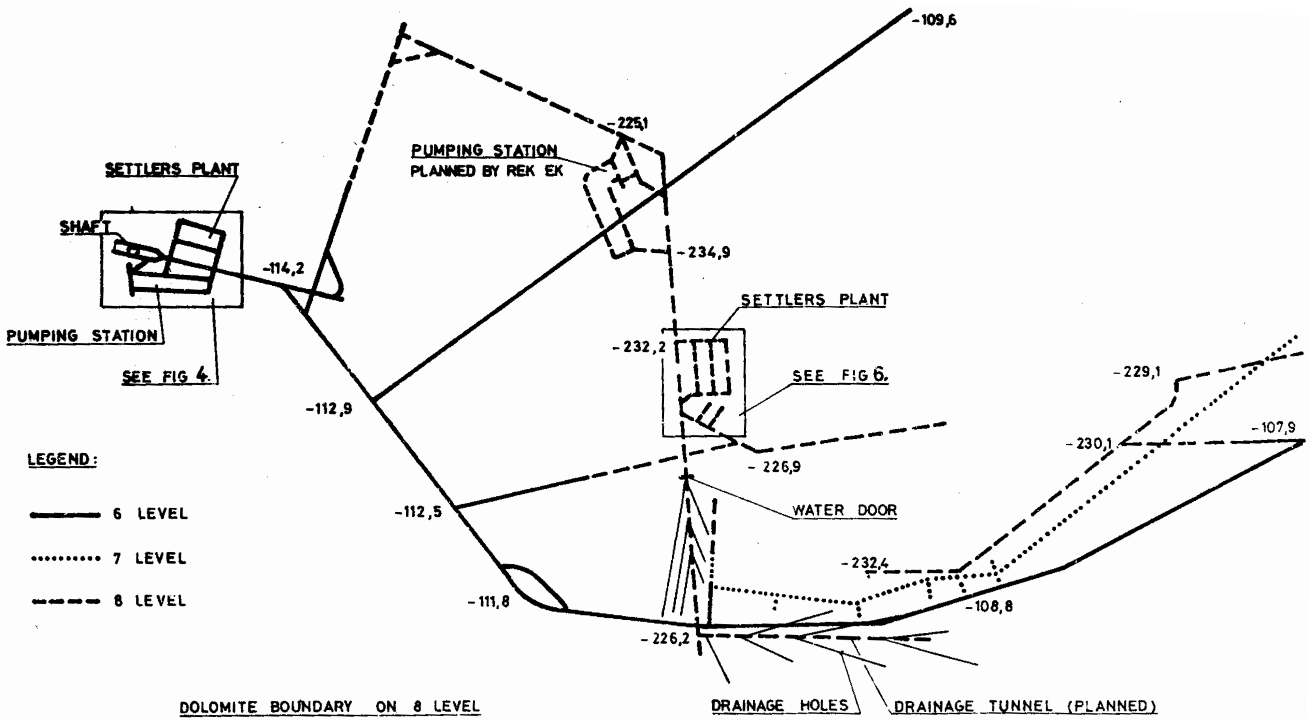

FIG. 5 DESIGN ON DRAINAGE OPERATIONS AND ON WATER TREATMENT AND PUMPING AT THE LEVEL 8

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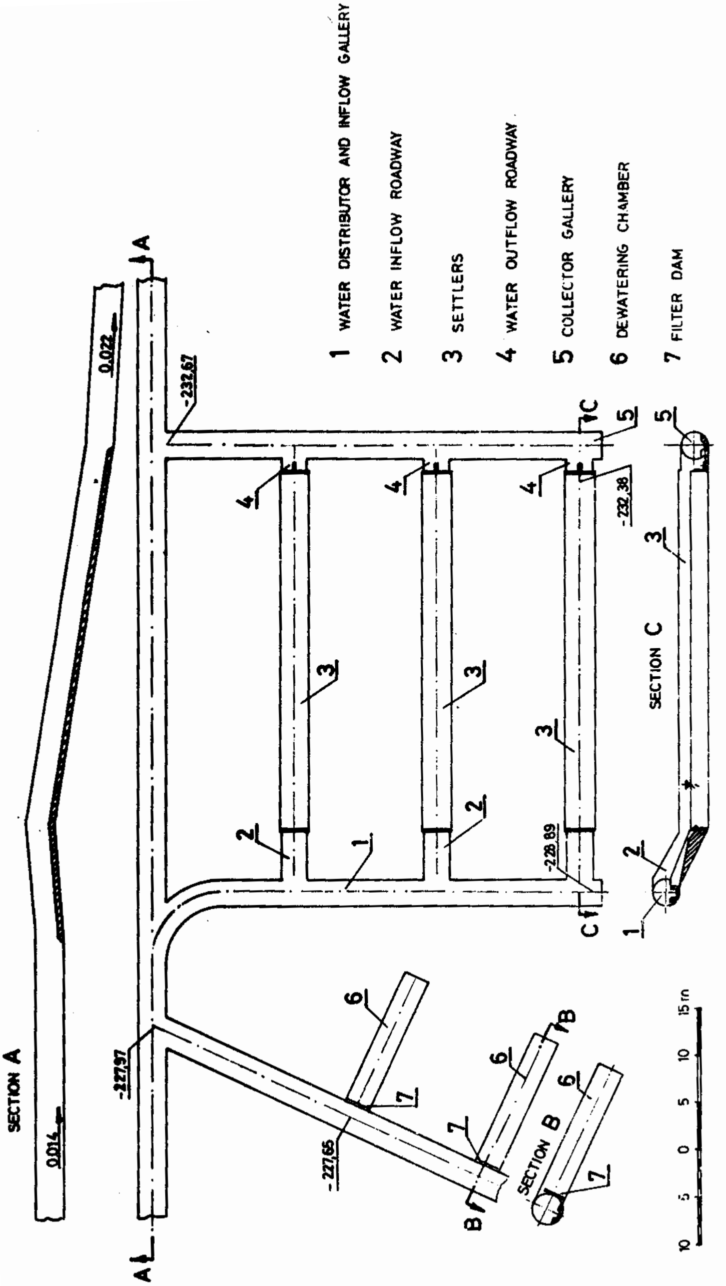

FIG. 6 DESIGN OF SETTING PLANT AT THE LEVEL 2

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- three or alternatively four injector pumps and one feeding pumps or TOYO gravel pumps for sediment removal,

- two dewatering chambers for dewatering and storage of the removed sediments,

- the dewatered sediment will be loaded by mine loading machines and transported by mine ears.

In case of using TOYO-gravel pumps the sediment can be removed even during operation. In this case only two settlers would be planned.

The location map and some sections of the settler can be seen in Fig. 6. /Bagdy-Kesserü 1976/
All details of the plant were designed on the basis of full scale tests carried on at the testing plant of our Institute /Kesserü-Bagdy 1978, Bagdy-Kocsányi 1982, Bagdy 1982/

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